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ORIGINAL ARTICLE

Studying Groundwater Corrosion and Sedimentation in Pressurized Irrigation Hydraulic systems Case study: Rafsanjan plain

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ABSTRACT
One of the first measures taken in designing an under pressure irrigation system is studying water qualitative properties. Almost all micro-irrigation systems require good quality water. However, the word 'good' is an infinite concept does not necessarily mean not consuming bad quality water in under pressure irrigation. Water exists in nature often contains impurities sometimes avoiding optimal usage of this critical source. Thus, different indices are proposed to detect and remove such water impurities, which prevent various problems and wasting financial resources. This research studied Rafsanjan plain in Kerman province, southeast Iran. Due to recent years' drought in country as well as water resource constraints, tendency toward pressurized irrigation systems, particularly drip irrigation, has increasingly increased in this area. Considering that all water resources in this area are groundwater, this paper studies corrosion and scaling property of ground waters of 70% areas of Rafsanjan plain in order to determine the effect of water corrosive factors or sedimentation on pressurized irrigation systems (including central facilities, suction pipe, driving pumps and connections, laterals and droppers). So, two Ryznar (RSI) and Langelier (LSI) indices are used. Data are analyzed through plain maps resulted from calculations of these two indices. Results show that 74.3 % of Rafsanjan plain areas have relatively corrosive and negligible sedimentation water, 20% noncorrosive, and non-sediment water, 4.3% relatively sediment and little corrosive water, 1.4% extremely corrosive; further, there is seen no extremely sedimented water sample.
Key terms: *Sedimentation, corrosion, pressurized irrigation hydraulic systems*

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INTRODUCTION

Water can cause corrosion in transmission and distribution lines as well as creating thick layers of sediment on heat exchange units' walls and surfaces. Corrosion is the gradual destruction of materials (usually metals) by chemical reaction with their environment, which leads to changing material's properties. The environment can be liquid such as solutions passing pipes and installations, and or solid such as the soil tubes' outer walls are exposed to. There are several chemical, physical, electric, and biological factors influence corrosion process. The physical and chemical factors influence corrosion include dissolved gases, temperature, hardness, calcium, alkalinity, PH, suspended material, dissolved solids, as well. Microbial corrosion most often occurs due to corrosive bacteria activities such as iron and sulfur bacteria. There have been different indices such as Ryznar, Langelier, and Pocorious applied to explain the extent of water corrosiveness [2, 4]. Most studies previously focused on visible effects of corrosion including deterioration, leakage, or economic damage; aesthetic and health aspects were rarely noticed. Since the world still keeps on using steel pipes for water transfer, water industry requires paying attention to water quality- corrosion interaction and the effect of corrosion on water quality [3]. several different studies are carried out on corrosion and water sedimentation (scaling). Rabbani et al (2011) in a study on identifying corrosion and scaling quality of rural water resources in Kashan using Ryznar,

Langelier, and Pocorious indices showed that most studied water resources are corrosive and a few have scaling property [4].
Another research studied aquifer corrosion and scaling potential in pressurized irrigation systems, in Lordegan plain, demonstrates that northern aquifer ground water have sedimentation and corrosiveness is seen in Jamal plain ground water [5]. Pour Saeidi et al (2008) used Ryznar and Langelier indices to show the extent of agricultural ground water corrosiveness and sedimentation in pressurized irrigation system of Jiroft plain. The results of Zarei et al [7] study on calcium carbonate sedimentation in drip irrigation systems of several provinces in Iran showed that Kerman, Khorasan, and Semnan provinces' water is classified as poor, average, and good quality, respectively.
Studying water quality properties is considered one of early measures in designing a pressurized irrigation system. Almost all hydraulic irrigation systems require good quality water. The term 'good', here, does not necessarily mean avoiding poor (bad) quality water in pressurized irrigation, as adjusting some designing criteria and or selecting proper equipment may make poor quality water usable. However, ignoring water quality as well as disregarding purification and chemical modification may lead to problematic system utilization in future. Thus, it is necessary to detect outputs' obstruction causes; then, apply removing or minimizing each cause.
This paper studies chemical quality of Rafsanjan plain ground water in terms of corrosion and scaling in pressurized irrigation systems.

MATERIALS AND METHODS

Chemical sediment of materials such as CaCo3 and obstruction activities are generally gradual processes hardly localize. High temperature or high pH also considered as part of sedimentation problem. Sulfate and calcium carbonate or sulfate and Magnesium carbonate and carbonated water produced by sedimentation, too. Salinity is the most important parameter of water chemical quality; however, it is not directly involved in obstruction unless soluble ions chemically react to produce non-soluble materials [8].
Sedimented calcium magnesium is the most common substance of carbonate and non-carbonate water in arid and semi-arid regions of Iran. Corrosion is as much important as sedimentation issue in pressurized systems especially in waters with low pH. Water has some critical characteristics playing a fundamental role in corrosion mechanism including concentration, dissolved oxygen, pH, temperature, velocity, etc [9].
Natural water often contains impurities that sometimes prevent optimal using of this critical substance. Hence, different indices are proposed for detecting and removing water impurities, which avoid various problems and wasting financial costs through measuring these chemical indices by using experiments' results. In this regard, different indices including Langelier Saturation Index (LSI), Ryznar Stability Index (RSI), and Calcium Carbonate sedimentation potential (CCPP) were used for the first index, which are largely applied both in industry and agriculture. This paper studies the amount of water corrosion and sedimentation used for agriculture in different parts of Rafsanjan plain; and finally, the research qualitatively studies this area's water.

Understudy area (case study)

Rafsanjan city is located in Kerman province, southeast of Iran. The case study is Rafsanjan plain with study area code of 4902. Rafsanjan area with a total height difference between 1400 and 1500 meters above sea level, and an area of approximately 10905 km^2 is situated in central plateau of Iran. 4636 km^2 of this area is plain and 6269 km^2 is mountainous. Its longitude and latitude are within 56° 32, 54° 30, 31° 15, and 29° 52, respectively. Figure 1 represents understudied area and Rafsanjan plain ground water resources.

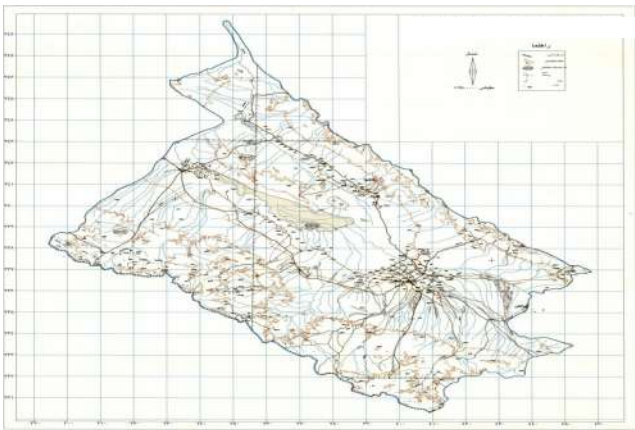

Figure 1: Understudy area and Rafsanjan plain ground water resources

Selecting studied parts
Considering the large extent of Rafsanjan plain and its large numbers of wells and aqueducts, 70 regions of this plain were selected and their average chemical parameters were studied in summer within 2007-2008, which are shown in Figure 1.
Langelier Saturation Index (LSI), Ryznar Stability Index (RSI)
Some methods and indices are introduced for determining water corrosion and sedimentation potential. Most of these indices hypothesized that water with calcium carbonate sediment on metal surfaces show less corrosion of which Langelier index (LSI) and Ryznar Stability Index (RSI) are the most popular methods. It is necessary noting that these methods usually rely on chemical balances determining what will occur; while, disregard problem dynamics. LSI and RSI are expressed as follows:

$PH_{measured}$- PH_{sat} = Langelier index [1]
- PH_{sat} $PH_{measured}$ = Ryznar Index [2]

Where, $PH_{measured}$ is water real PH, and PH_{sat} is calcium carbonate ($CaCo_3$) saturated PH obtained as follows:

$$PH_{sat} = -\log\left[\frac{(k_2)(\gamma Ca^{2+})[Ca^{2+}])(\gamma_{HCo_3^-})[H_{Co_3^-}]}{(k_{sp})}\right] [3]$$

$[Ca^{2+}]$= Calcium concentration (m/l)
$[H_{Co_3^-}]$=Calcium concentration (m/l)
K_s = Carbonate equation coefficient (m/l)
K_{sp} = Carbonate equation coefficient (m/l)
K_s and K_{sp} obtain from corresponding table, which are in terms of temperature.
$H_{Ca^{2+}}$ and $\gamma H_{Co_3^-}$ are reaction coefficients calculated as follows:

$$\log\gamma_{HCo_3^-} = -\frac{0.5\,(Zi^2)\mu^{0.5}}{1+\mu^{0.5}} [4]$$
$$\mu = 2.5 \times 10^{-5} \times TDS [5]$$

TDS= remaining evaporated amount (gr/m^3)
Where, Zi is Ca^{2+} and Hco_3^- ion exchange capacity.
LSI inference is as follows:
LSI<0: there is no curst formation potential and water dissolves $CaCO_3$ (corrosion)
LSI=0: imbalance (corrosion and sedimentation unwillingness)
LSI>0: tendency to curst formation ($CaCO_3$ sediment).
And, RSI inferential is as follows:
RSI<<6: increased tendency to sedimentation and film formation
RSI>>7: Calcium carbonate sediment, which possibly produces no protective film
RSI>>8: increased mild corrosive problem in steel pipes

In general, if real pH in Langelier method is computed smaller than pH_{sat}, then LSI will be negative dissolving calcium carbonate and water will have corrosive characteristic. While, if water real pH is larger than pH_{sat}, then LSI is positive saturating water with $CaCO_3$ and must be considered in designing such systems. LSI is only practical for $CaCO_3$ sedimentation in a medium with low TDS and small boundaries. Any index surface impurity (pollution) and oil makes error. In addition, this index is applied in systems with low flow rate. Since Langelier index merely represents water tendency or no tendency to sedimentation, it is not regarded a quantitative measurement factor. Ryznar adjusted Langelier index considering corrosion and sedimentation results report in urban water networks. This experimental index is used for systems with over 2 f/s (0.6 m/s) water flow rate. The results are provided in Figures 2 and 3.

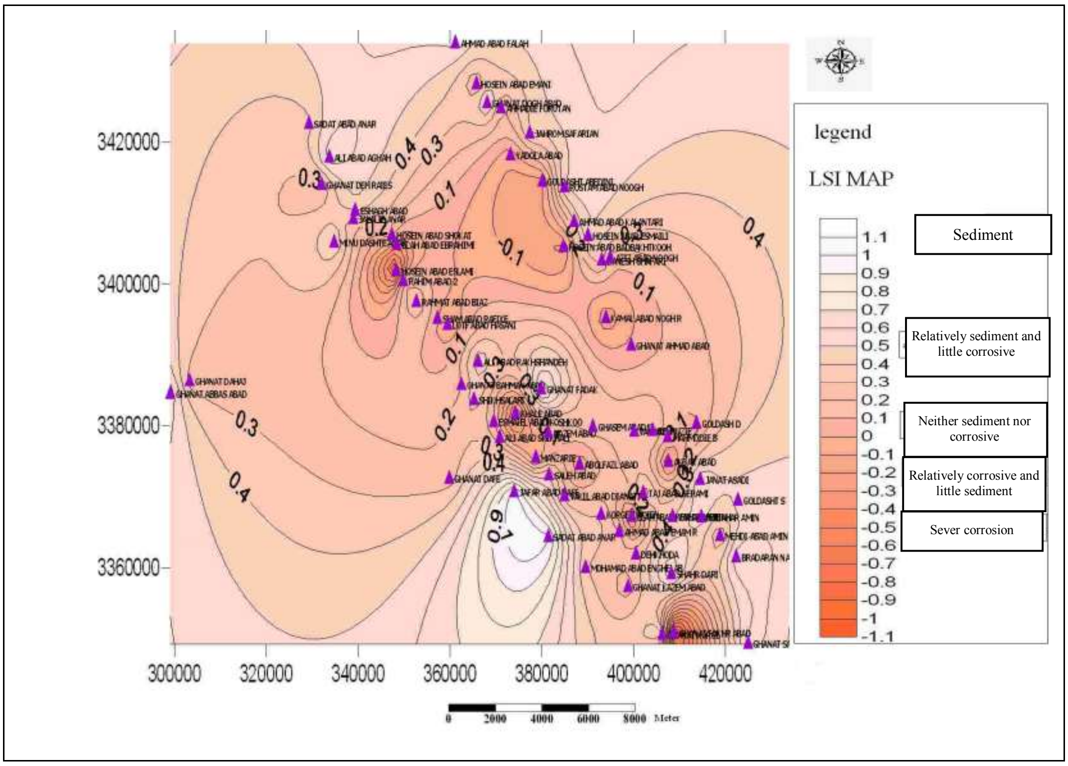

Figure 2: LSI corresponding curves

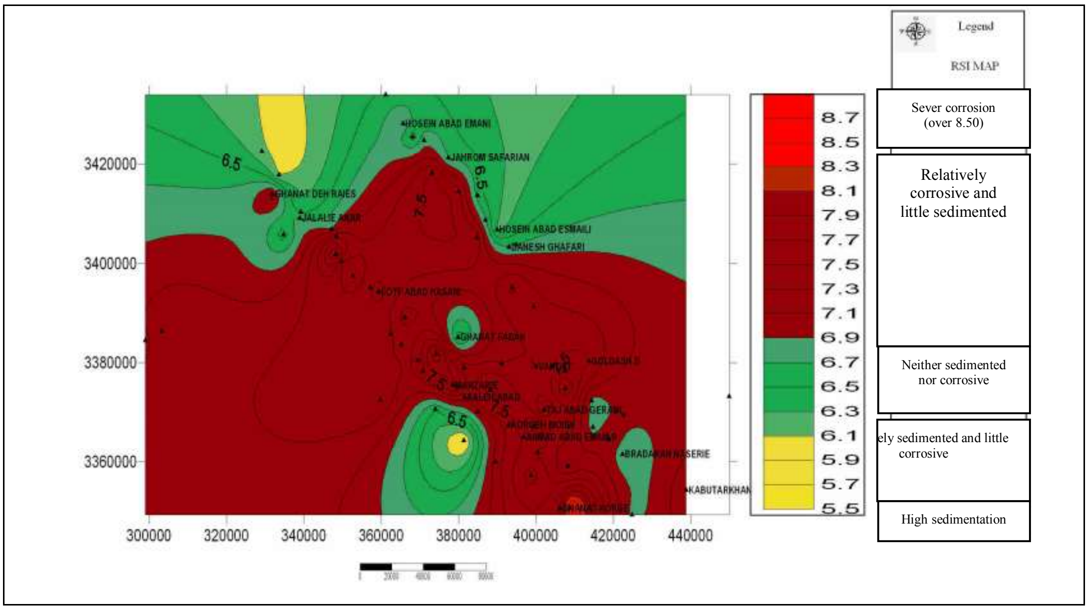

Figure 3: RSI corresponding curves

RESULTS AND DISCUSSION

Required computations and Langelier and Ryznar indices obtained by using Excel software according to equations (1) and (2), the results are presented in Table 2 as follows:

No.	Place	Status using RSI	RSI	LSI	Number	Place	Status using RSI	RSI	LSI
1	Lower Abbasabad aqueduct	Relatively corrosive and little sedimentation (8.50-80)	7.03	0.68	36	Hossein Abad Badbakhtkouh	Relatively corrosive and little sedimentation (8.50-6.80)	7.47	0.68
2	Langroud Dehj aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.3	0.24	37	Nough Rostam Abad	Neither corrosive nor sedimented (6.80-6.20)	6.58	0.5

3	Saadat Abad Anar	Relatively sedimented and little corrosive (6.20-5.50)	6.15	0.37	38	Vakil Abad Dianati	Relatively corrosive and little sedimentation (8.50-6.80)	7.04	0.22
4	Dah Raies aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.20	0.19	39	Ahmad Abad Kalantari	Neither corrosive nor sedimented (6.80-6.20)	6.71	0.29
5	Ali Abad Agah	Relatively sedimented and little corrosive (6.20-5.50)	6.05	0.67	40	Abolfazl Abad	Relatively corrosive and little sedimentation (8.50-6.80)	7.86	-0.08
6	Minoodasht Anar	Neither corrosive nor sedimented (6.80-6.20)	6.36	0.51	41	Mohammad Abad Enqelab	Relatively corrosive and little sedimentation (8.50-6.80)	7.19	0.3
7	Jalalie Hejri	Relatively corrosive and little sedimentation (8.50-6.80)	6.83	0.18	42	Hossein Abad Ismaeilie	Neither corrosive nor sedimented (6.80-6.20)	6.21	0.49
8	Ishagh Abad	Neither corrosive nor sedimented (6.80-6.20)	6.34	0.47	43	Ghasem Abad Karbalie Gha	Relatively corrosive and little sedimentation (8.50-6.80)	7.28	0.25
9	Hossein Abad Shokat	Relatively corrosive and little sedimentation (8.50-6.80)	6.86	0.16	44	Koorgah Moein	Relatively corrosive and little sedimentation (8.50-6.80)	7.38	0.3
10	Hossein Abad Islami	Relatively corrosive and little sedimentation (8.50-6.80)	8.24	-0.77	45	Danesh Ghafari Ismaeil	Neither corrosive nor sedimented (6.80-6.20)	6.72	0.33
11	Allah Abad Ibrahimi	Relatively corrosive and little sedimentation (8.50-6.80)	7.45	-0.27	46	Kamal Abad Nough Rezvan	Relatively corrosive and little sedimentation (8.50-6.80)	7.55	-0.17
12	Rahim Abad Number 2	Relatively corrosive and little sedimentation (8.50-6.80)	7.27	0.16	47	Aziz Abad Nough	Neither corrosive nor sedimented (6.80-6.20)	6.71	0.14
13	Rahmat Abad Beyaz	Relatively corrosive and little sedimentation (8.50-6.80)	7.1	0.29	48	Ahmad Abad Emam Reza	Relatively corrosive and little sedimentation (8.50-6.80)	7.52	0.23
14	Shahem Abad Rafie	Relatively corrosive and little sedimentation (8.50-6.80)	7.49	0.00	49	Kazem Abad aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.83	0.13
15	Lotf Abad Aboul Hassani	Relatively corrosive and little sedimentation (8.50-6.80)	7.58	-0.14	50	Rouy Ghanat Ahamad Abar rasou	Relatively corrosive and little sedimentation (8.50-6.80)	7.35	0.02
16	Ahmad Abad Deife aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.5	0.24	51	Allah Abad Keshavarzi	Relatively corrosive and little sedimentation (8.50-6.80)	8.1	-0.35
17	Ahmad Abad Fallah	Neither corrosive nor sedimented (6.80-6.20)	6.55	0.62	52	Vahdat	Relatively corrosive and little sedimentation (8.50-6.80)	7.28	0.25
18	Rouy Ghanat Bahman Abad	Relatively corrosive and little sedimentation (8.50-6.80)	7.34	0.17	53	Deh Khoda	Relatively corrosive and little sedimentation (8.50-6.80)	7.44	0.27
19	Sheikh Salari Farahzad	Relatively corrosive and little sedimentation (8.50-6.80)	7.20	0.34	54	Taj Abad Kohne Gerami	Relatively corrosive and little sedimentation (8.50-6.80)	7.02	0.48
20	Hossein Abad Emami	Relatively corrosive and little sedimentation (8.50-6.80)	6.9	0.19	55	Behrouzie Abdollahi Number 2	Relatively corrosive and little sedimentation (8.50-6.80)	7.42	0.33
21	Ali Abad Derakhshande	Relatively corrosive and little sedimentation (8.50-6.80)	6.99	0.5	56	Kour Ke aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.4	0.44
22	Rouy Ghanat Dough Abad	Neither corrosive nor sedimented (6.80-6.20)	6.35	0.57	57	Mahmoudie Bahrami	Relatively corrosive and little sedimentation (8.50-6.80)	7.59	0.1
23	Ismaeil Abad Kashkou	Relatively corrosive and little sedimentation (8.50-6.80)	7.35	0.12	58	Akbar Abad Hejri	Relatively corrosive and little sedimentation (8.50-6.80)	7.93	-0.21
24	Ali Abad Haj Sheikh	Relatively corrosive and little sedimentation (8.50-6.80)	7.43	0.13	59	Shahrdari Number 6	Relatively corrosive and little sedimentation (8.50-6.80)	7.05	0.72
25	Shomal Ahmadie Foroutan	Relatively corrosive and little sedimentation (8.50-6.80)	6.85	0.17	60	Varase Shiekh Agha	Relatively corrosive and little sedimentation (8.50-6.80)	7.42	0.38
26	Yadollah Abad Nough	Relatively corrosive and little sedimentation (8.50-6.80)	7.53	-0.06	61	Fakhr Abad aqueduct	Sever corrosion (Over 8.50)	8.7	-1.05

27	Jafar Abad Defe	Neither corrosive nor sedimented (6.80-6.20)	6.49	1.05	62	Goldasht Davaran	Relatively corrosive and little sedimentation (8.50-6.80)	7.51	0.09
28	Khalegh Abad	Relatively corrosive and little sedimentation (8.50-6.80)	8.13	-0.51	63	Janat Asadi	Relatively corrosive and little sedimentation (8.50-6.80)	6.81	0.59
29	Jahrom Safarian	Neither corrosive nor sedimented (6.80-6.20)	6.66	0.41	64	Nobahar Aminian	Neither corrosive nor sedimented (6.80-6.20)	6.79	0.55
30	Manzarie	Relatively corrosive and little sedimentation (8.50-6.80)	7.77	-0.08	65	Mehdi Abad Aminian	Relatively corrosive and little sedimentation (8.50-6.80)	7.157	0.17
31	Fadak aqueduct	Neither corrosive nor sedimented (6.80-6.20)	6.35	0.82	66	Naserie brothers	Neither corrosive nor sedimented (6.80-6.20)	6.72	0.68
32	Goldasht Abedini	Relatively corrosive and little sedimentation (8.50-6.80)	7.40	-0.15	67	Golshan Sefidrooud	Relatively corrosive and little sedimentation (8.50-6.80)	6.95	0.52
33	Sadat	Relatively sedimented and little corrosive (6.20-5.50)	5.85	1.02	68	Saadat abad aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	6.83	0.63
34	Kazem Abad	Relatively corrosive and little sedimentation (8.50-6.80)	7.39	0.05	69	Hagh abei Kaboutar khan	Relatively corrosive and little sedimentation (8.50-6.80)	7.26	0.36
35	Saleh Abad	Relatively corrosive and little sedimentation (8.50-6.80)	7.16	0.41	70	Khenaman aqueduct	Relatively corrosive and little sedimentation (8.50-6.80)	7.26	0.51

Table 2: ground water places and their status using RSI index

Obtained results demonstrate that there is a significant difference between two indices in some regions, which is usually seen. However, as analyzing results with Ryznar index are more valid, this index is more used. According to RSI, 74.3% of Rafsanjan plain areas have relatively corrosive with little sedimentation water, 20% are neither corrosive, nor sedimented, 4.3% have relative sedimentation with little corrosion, 1.4% have strong corrosive water, and there was no water with high sedimentation. The results are presented in Table 2.

Table 2: Samples results in terms of corrosion and sedimentation

%	Numbers	Results
0	0	High sedimentation (Less than 5.5)
4.3	3	Relatively sedimented and little corrosive (6.20-5.50)
20	14	Neither sedimented nor corrosive (6.20-6.80)
74.3	52	Relatively corrosive and little sedimentation (8.50-6.80)
1.4	1	Sever corrosion (over 8.50)

According to developing agricultural pressurized systems in Rafsanjan plain and increased willing of applying irrigation pressurized systems, especially drip irrigation, it is required to paying attention to designing, maintenance, as well as utilization management (corrosion and sedimentation in particular) of such systems. This paper studying 70 regions of the aforementioned plain reveals regions with corrosion and sedimentation characteristics. It is necessary to take required measures, as this issue will lead to challenges in long-term.

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